Human Ecology, Vol. 27, No. 1, 1999

Rangeland Mismanagement in South Africa: Failure to Apply Ecological Knowledge

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Chronic, heavy livestock grazing and concomitant fire suppression have caused the gradual replacement of palatable grass species by less palatable trees and woody shrubs in a rangeland degradation process termed bush encroachment in South Africa. Grazing policymakers and cattle farmers alike have not appreciated the ecological role fire and native browsers play in preventing bush encroachment. Unpredictable droughts are common in South Africa but have deflected too much blame for bush encroachment away from grazing mismanagement. Bush encroachment is widespread on both black and white farms, although the contributing socioeconomic, cultural, and political forces differ. Managers at Madikwe Game Reserve have reintroduced fire and native game animals into a formerly overgrazed system in an attempt to remediate bush encroachment, with encouraging preliminary results. A bush control program is needed that educates cattle farmers about the ecological causes of bush encroachment and encourages the use of fire and native browsers as tools for sustainable grazing management.

KEY WORDS: bush encroachment; carrying capacity; grazing policy; rangeland management; stocking rate.

INTRODUCTION

Rangeland degradation has been observed on every continent where arid and semi-arid savannas occur (Archer, 1995). Because they are usually

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0300-7839/99/0300– 0055$16.00/0

too dry to support most crops, rangelands are predominantly used for cattle grazing. Livestock grazing is the primary cause of desertification globally (Mabbutt, 1984). The proportion of arid rangelands desertified has not been adequately quantified but is believed to be 49–90% in Africa (Graetz, 1994). Many scientists have discussed potential links between desertification and global climate change but no clear link has been established (e.g. Glantz, 1992). In the Republic of South Africa (RSA), the location of this study, neither Tyson (1987) nor Vogel (1988a,b) found evidence for climate change over the past 150 years.

A less well-known, more subtle, yet widespread form of rangeland degradation is encroachment by generally unpalatable trees and shrubs at the expense of palatable grasses over a time span of several decades. South Africans refer to this phenomenon as bush encroachment. Climate change and the increasing atmospheric carbon dioxide concentration have been suggested as causes for bush encroachment, but much stronger evidence implicates livestock grazing as the cause (Archer *et al.*, 1995). In the southern Africa region, heavy grazing by domestic livestock is considered the main cause for vegetation degradation (Ringrose *et al.*, 1990), and many studies have suggested that heavy grazing reduces the productivity of semi-arid rangelands (Acocks, 1953; Talbot, 1961; Downing, 1978; Huntley, 1978; Roux and Vorster, 1983). Bush encroachment decreases grazing capacity (Richter, 1990), increases transpiration (thus lowering the soil moisture available for grass growth) (Donaldson, 1967), and decreases weaner calf production (Moore and Odendaal, 1987)—all of which lead to economic hardship for cattle farmers.

Africa contains the largest proportion of the savanna biome, comprising 43 million ha in the Republic of South Africa (RSA) alone, 84% of which is used for livestock ranching (Grossman and Gander, 1989). Thirty-five years ago, van der Schijff (1964) estimated that 18 million ha of savanna in RSA were seriously encroached by bush or were susceptible to bush encroachment. According to more recent assessments, bush encroachment has rendered 1.1 million ha of South African savanna unusable, threatens another 27 million ha, and has reduced the grazing capacity[2] throughout the region by up to 50% (Grossman and Gander, 1989).

Bush encroachment is considered a problem in the two localities targeted for this study (Fig. 1); the reasons are different but both are economic. At Ganyesa, livestock farming is the bulwark of the local economy, and bush encroachment has caused marked declines in carrying capacity (CC). At Madikwe, livestock farming is also an economic mainstay except within

[2]The grazing capacity, or ecological carrying capacity (CC), is the maximum population of grazers that the vegetation can support at a given time.

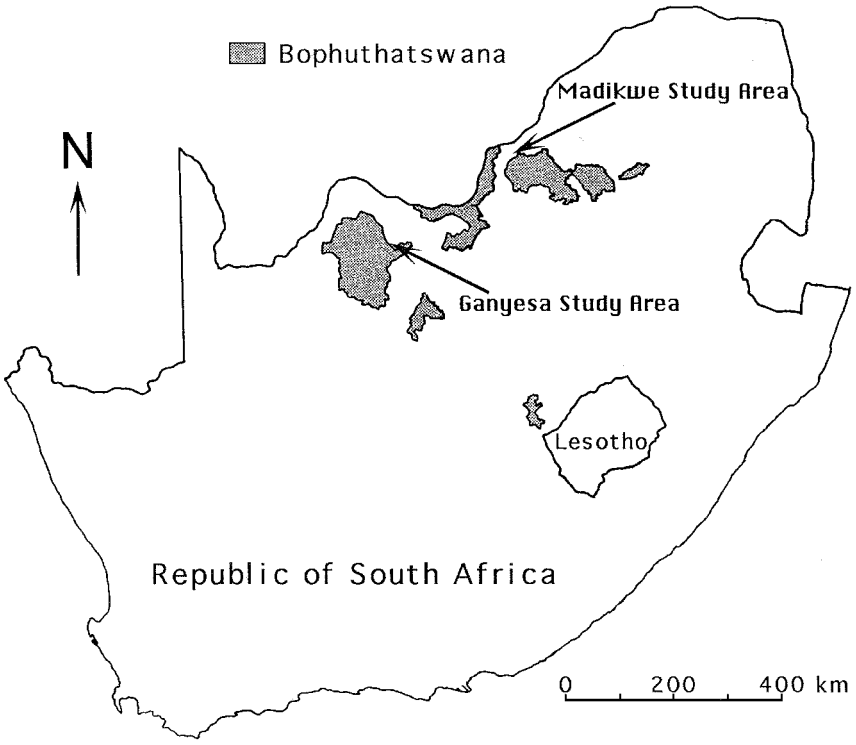

Fig. 1. Location of Ganyesa and Madikwe study areas.

Madikwe Game Reserve (MGR). Farmers outside the reserve are concerned about bush encroachment for the same reason as Ganyesa farmers; ecological managers for MGR are mainly concerned because thick bush interferes with game viewing by tourists.

This paper is composed of five parts. First, I provide necessary background information to give context to the human ecology surrounding the bush encroachment problem in this region. Second, I contrast a statistical analysis of long-term rainfall records with local farmers' tendency to first blame drought for bush encroachment rather than overstocking. Third, I present evidence of historic overstocking by cattle farmers and expose the ecological failure of past grazing management policy and practice. Fourth, I compare the management philosophy currently being applied in MGR to that applied by its main former occupant. Fifth, based largely on the MGR model, I offer some recommendations for more sustainable rangeland management.

BACKGROUND

Savanna Ecology

Savannas are defined as having a continuous grass understory interspersed by a discontinuous woody overstory. Productivity of arid and semi-arid savannas is primarily determined by rainfall (Rutherford, 1980; van den Berg, 1983; Le Houérou *et al.*, 1988; Le Houérou, 1989). Seasonal drought in this semi-arid savanna region lasts from approximately mid-April to mid-November, with rainfall declining along a longitudinal gradient from east to west. Interannual drought is common but unpredictable. Grass growth is vigorous in years with ample rainfall, raising fuel loads and fire risk during the dry season. Natural savanna fires are ignited by lightning from dry thunderstorms that precede the arrival of more substantial rain. Fire kills trees of insufficient height, while grasses resprout very quickly. Fire therefore tilts the competitive balance between trees and grasses in favor of grasses (Coughenour and Ellis, 1993). Several years without a fire allows tree seedlings to establish (Conant, 1982). Herbivores add another component to savanna ecology. Grazing frees more resources for tree seedlings competing with grasses (von Maltitz, 1991), while browsing serves as a check on woody plant growth.

Ecologists have established the existence of thresholds of environmental change between domains of relative stability (Holling, 1973; Wissel, 1984). Savannas are inherently unstable, with the ratio of woody plants/grasses determined by climate, soils, and fire and herbivore disturbance regimes. Savanna species are adapted to withstand high variability in these determinants. For example, Danckwerts and Stuart-Hill (1988) found that when grazing livestock were withdrawn for 6 months after a drought ended, palatable grasses quickly recovered to their former abundance. Even so, the combination of heavy grazing and fire suppression over many decades appears to push the system beyond the threshold into a relatively stable state that is not readily reversed through natural processes. Encroaching bush can ultimately form virtually impenetrable, thorny thickets, which monopolize light, water and nutrient resources and permit little or no grass growth underneath (Belsky and Canham, 1994). The paucity in grass fuel beneath woody thickets makes them resistant to burning (Scholes, 1987). Thus, an inherently unstable grassland savanna can gradually transform into a relatively stable thorn woodland (Archer, 1990).

Bush encroaches at large spatial and temporal scales, making it hard to perceive until it is quite far advanced. It is difficult to measure the magnitude of bush encroachment when no ungrazed land remains with which objectively to compare it. In summary, bush encroachment is a

textbook but underpublicized example of a creeping environmental phenomenon, the term coined by Glantz (1994a) to describe many long-term, slow-onset environmental degradations that may proceed to great magnitude before the need for remediative action is realized or remediative action taken.

Remediative efforts to improve rangeland condition have generally focused on providing drought relief, which typically consists of drilling more boreholes to provide water to cattle year round and over wider areas. The ecological effects of this strategy have proved disastrous. The availability of permanent drinking stations exposes grasses to continuous grazing pressure, to which they are not adapted. Thus, creating permanent drinking stations to improve rangelands actually backfires and exacerbates deterioration of the grass resource base (Glantz, 1976; Picardi and Siefert, 1976).

Grazing History

Grazing has been the predominant land use practice in savanna ecosystems for generations. Tswana pastoralists have grazed cattle in north-central South Africa for as long as documentation exists, with cattle historically playing a central role in Tswana economy, culture and society (Comaroff and Comaroff, 1991). Pastoral nomadism was formerly perceived as destructive by grazing analysts. Hardin (1968) first proposed the Tragedy of the Commons, the idea that communal grazing was doomed to deplete the resource base because the costs of exploiting the free grass resource are passed on to society while the benefits are enjoyed solely by individual herders—making exploitation always the more attractive option for all herders. More recent research has largely debunked this notion that pastoralism is inherently destructive to the environment and shown it is an ecologically sustainable strategy at low enough population densities (McCay and Acheson, 1987; Feeny *et al.*, 1990; McCabe, 1990; Reid and Ellis, 1995).

The nineteenth-century arrival of the white Trekboers (and their livestock) into interior South Africa during "the Great Trek" north from the Cape Colony (Marx, 1993) dramatically altered historic savanna ecology. Cattle and sheep, having a restrictive dietary preference for a few grass species, replaced the diverse array of indigenous grazing and browsing ungulates, along with the pastoral cattle herds. Fencelines were erected to restrict livestock movements, which shortened or eliminated vegetation recovery periods.

Constraining livestock movements forces livestock to graze the same pasture continuously, which consequently reduces ecosystem resilience, or the ecosystem's ability to respond to varying climatic conditions (Perrings

et al., 1995; Niamir-Fuller, 1998). Boreholes and wells were also established, further facilitating continuous grazing of vegetation adapted to rest during the dry season. Finally, natural veld[3] fires were either actively suppressed by farmers or passively precluded by livestock that ate or trampled the grass which would have fueled fires. Such alterations to fire and herbivore disturbance regimes have caused the bush encroachment commonly observed today in South African veld (Hoffman, 1997).

Study Areas

The two areas targeted for this study, Ganyesa and Madikwe, are named after separate parcels of the former bantustan (Black homeland) of Bophuthatswana (BOP), scattered across north central South Africa near the Botswana border. The two study areas straddle the former BOP border with RSA, allowing comparison between Black and White cattle farms (see Fig. 1). BOP was officially established in 1977 for the Tswana tribe in belated accordance with the 1936 Native Trust and Land Act, although Blacks already had been forced to settle there for many years. Crowding of men and beasts was reported as far back as 1941 (De Kiewiet, 1941). In 1949, human population densities were over four times greater inside the Black reserves than in White-controlled areas (Roux, 1949)—and growing faster. Generally, the bantustans contain land of inferior quality, with denser human settlement patterns, poorer ecological integrity, and reduced agricultural potential (Butler *et al.*, 1977; SETPLAN, 1990; Vogel, 1994). BOP and the other bantustans were assimilated into RSA when apartheid ended and the African National Congress was elected into power in 1993.

Most farms included in this study were former white farms bought out by the RSA government for fair market value and handed over to BOP in the early 1980s as South African Development Trust (SADT) Farms. A recent analysis of historical aerial photographs suggests that these farms were already heavily encroached at the time of transfer (Hudak and Wessman, 1998). In 1991, the BOP government commissioned a survey in the Madikwe area to recommend the most efficient form of land use for 60,000 ha of geologically and biologically diverse veld that had been severely overgrazed. This survey precipitated the creation of MGR. To quote the MGR vision statement, "The ecological management will be focused on restoring Madikwe to its former state with a view to enhancing the visitor experience." The phrase "restoring Madikwe to its former state" refers to

[3]"Veld" is the South African equivalent of what Americans refer to as "range."

remediating heavy bush encroachment resulting from a ''legacy of mismanagement'' from cattle farming (Madikwe Development Task Team, 1994).

BLAMING DROUGHT

''Drought'' is popularly viewed as a solely meteorological phenomenon even though it is only perceived when it adversely affects society (Glantz, 1994b). The detrimental effects of low rainfall are more likely felt among inhabitants of overexploited lands, found typically in underdeveloped regions such as the one chosen for this study. It has been established since 1923 that land mismanagement and overexploitation have aggravated drought impacts in RSA (Vogel, 1994). Severe drought in the 1980s caused alarming degradation to veld vegetation, sparking development of a National Grazing Strategy (du Toit *et al.*, 1991). Nationwide surveys of cattle farmers found that they considered overgrazing more of a problem than the drought itself (Vogel, 1994).

Nevertheless, 16 out of the 17 farmers asked in this local study to name the causes for bush encroachment ***first*** blamed drought. To further explore this viewpoint, I obtained monthly rainfall records from rainfall monitoring stations located either within or in very close proximity to the Ganyesa ($N = 14$ stations) and Madikwe ($N = 18$ stations) study areas. For each area, I chose the station with the longest rainfall record for time series analysis, after first confirming that the long-term mean of these two stations was within one standard deviation of the mean for the respective area stations combined. The Ganyesa station chosen was Morokweng (87-year record) and the Madikwe station chosen was Nietverdiend (70-year record). Regressions of annual rainfall on year proved insignificant at Morokweng ($y = 0.052x - 75.59$; $R^2 = 0.038$; $p = 0.219$) and Nietverdiend ($y = -0.016x + 72.56$; $R^2 = 0.006$; $p = 0.856$), indicating no detectable long-term rainfall trend.

Arid and semi-arid regions are typified by high interannual rainfall variability, however, making it very difficult to detect long-term change (Glantz, 1994b). Indeed, high interannual rainfall variability at Morokweng and Nietverdiend made any potential, decadal-scale rainfall patterns difficult to discern from the annual rainfall records shown in Figs. 2a and b. Therefore, I explored the monthly rainfall records[4] more thoroughly using

[4]No rain falls for several months during the dry winter in South Africa, causing substantial positive skew in the Morokweng (skewness statistic = 1.85) and Nietverdiend (skewness statistic = 1.94) monthly rainfall records. Therefore, before calculating autocorrelation in these records, I normalized them using a square root transformation, which reduced their skewness statistics to 0.49 and 0.45, well below the most widely recognized upper limit of 1.0 for a normal distribution.

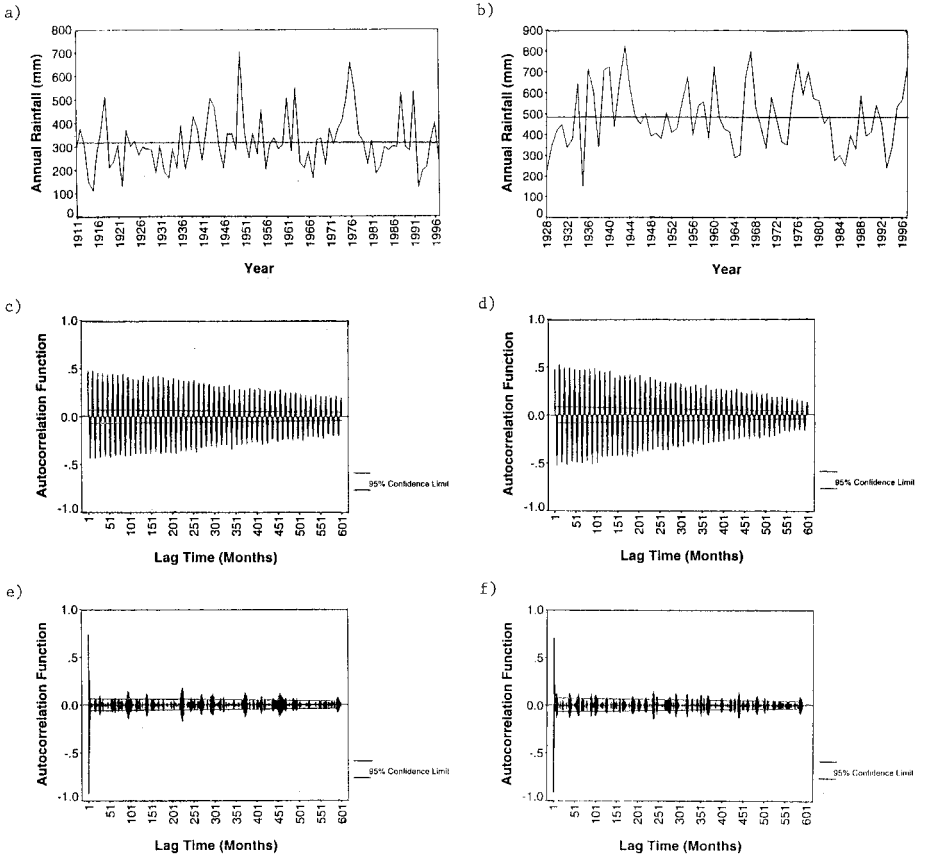

Fig. 2. Annual rainfall recorded at the (a) Morokweng (Ganyesa area), and (b) Nietverdiend (Madikwe area) rainfall stations, with mean annual rainfall indicated by the horizontal lines; autocorrelation function of monthly rainfall data from (c) Morokweng (March 1911–September 1997), and (d) Nietverdiend (March 1928–October 1997); first difference transformation to remove the annual periodicity from the autocorrelation functions for the (e) Morokweng and (f) Nietverdiend rainfall records. Source: Institute for Soil, Climate and Water, Pretoria, RSA.

the statistical autocorrelation function. Autocorrelation is a measure of the self-similarity of a sequence, calculated at successive positions throughout the sequence (Davis, 1986). Data in the sequence must be separated by equal intervals, so I substituted the long-term monthly mean for the few missing observations in each time series. Furthermore, autocorrelation is calculated at increasingly broader intervals, known as lags, up to a specified limit. Lags that approach the length of the entire series can cause erratic

behavior in the autocorrelation function because fewer intervals can be sampled. Since the shorter, Nietverdiend record was 70 years long, I conservatively chose a maximum lag of 600 months (50 years) and, for consistency, applied it to the Morokweng record as well.

The autocorrelograms shown in Figs. 2c and d exhibit the strong 12-month periodicity in the rainfall records. This periodicity was removed via a first difference transformation, which essentially omits the 12-month lag from calculations of the autocorrelation function. The resulting first difference autocorrelograms shown in Figs. 2e and f are useful for revealing more subtle patterns in temporal variation. This differencing operation can be iterated to successively subtract other periodicities from the record. However, since no more periodicities are apparent in these records, no further difference transformations were performed. The significant deviations of these correlograms beyond the 95% confidence intervals is evidence of significant interannual rainfall variability. The fact that they are unevenly spaced with regard to lag is evidence that this variability is unpredictable. These results indicate that significant drought events (and high rainfall periods) lasting several years occur frequently but unpredictably, which corroborates an earlier, regional analysis of rainfall records by Zucchini *et al.* (1992). The RSA Department of Agriculture (DA) has a drought relief program conceived from the National Grazing Strategy, which stipulates that drought disaster relief should be given only to farmers known to be practicing conservation measures (Vogel, 1994). I learned more about this drought relief program by interviewing Jannie van den Heever, senior agricultural extension agent for the DA in Vryburg District (which includes Ganyesa District since the 1993 dissolution of BOP). Only farmers who periodically report their stocking rates (SRs) to the DA are eligible for drought relief. In the event of a drought, a farmer must sell 1/3 of his livestock. Thus, farmers typically report SRs approaching 100% of CC, which decline to approximately 60% of CC during a drought. A reduced SR then must be maintained until 2 months beyond the end of the drought to give the vegetation time to recover. However, 2 months can hardly be called long term. Vogel (1994) similarly reports that agricultural subsidies from the RSA government are doled with little attention given to mid- to long-term sustainability of agricultural activities.

Düvel and Scholtz (1992) showed that South African farmers generally believe the long-term CC of their land to be higher than do the agricultural extension agents who advise them. Moreover, the DA cannot force farmers to adhere to the SRs recommended by its extension agents. Drought subsidies are paid only to those farmers who stock at officially recommended rates, but there are loopholes in this system. For instance, "real" livestock numbers may exceed those reported in tax returns or agricultural censuses

(Jannie van den Heever, personal communication), a factor also noted by Dean and Macdonald (1994). Yet this is not a recent development, and agricultural returns very likely have always been conservative (Dean and Macdonald, 1994). Historically, potential receipt of financial aid appears to be more important than agricultural potential in determining SR (Dean and Macdonald, 1994), so South African veld has tended to be overstocked rather than understocked (Talbot, 1961; Danckwerts and King, 1984; Danckwerts and Marais, 1989; Düvel and Scholtz, 1992; Dean and Macdonald, 1994).

Defining drought is difficult at best. Perhaps for this reason, governments prefer to blame drought on natural factors rather than societal factors when agricultural production declines or fails (Glantz, 1994b). I submit that it is this same human tendency for deferring blame that causes many cattle farmers to perceive droughts as highly unfortunate events rather than normal manifestations of a climate with unreliable rainfall.

EVIDENCE OF MISMANAGEMENT

Conservation committees in the 1950s determined CCs nationally for the various veld types; the DA has the responsibility for updating CC assessments as veld conditions change (Jannie van den Heever, personal communication). In BOP, this task fell upon a parastatal named the Agricultural Development Corporation of Bophuthatswana Ltd. (Agricor). Table I reveals that overstocking is not just a recent practice in the three former BOP districts situated within the study region. Note that CCs were reduced from 1950s estimates as far back as 1978. A similar Agricor study in 1984, a drought year, determined overstocking to be 352%, 170%, and 200% for Ganyesa, Madikwe, and Lehurutshe Districts, respectively. Since it is unlikely that actual SRs increased 3- to 8-fold in only 6 years, the increased overstocking more likely reflects further decline in CC.

Le Houérou (1989) showed that declining SRs reflect decreases in veld CC resulting from heavy and continuous overstocking. Dean and

Table I. Percent Overstocking in Three Bophuthatswana Districts in 1978[a]

District	Stocking rate (ha/LSU/yr)	Carrying capacity (ha/LSU/yr)	% Overstocked
Ganyesa	7.97–8.44	12	42.2
Madikwe	5.13–4.37	6	37.3
Lehurutshe[b]	3.81–3.61	6	66.2

[a]Source: Agricor annual report (1978).
[b]Lehurutshe District is located between Ganyesa and Madikwe Districts.

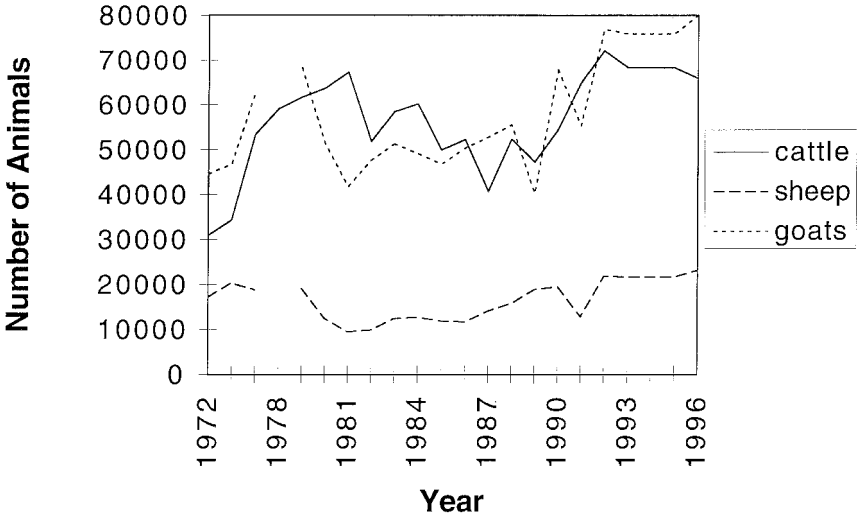

Fig. 3. Livestock population trends in Ganyesa District, 1972–1996. Source: Agricor annual reports (1972–1996).

Macdonald (1994) provided SR evidence that the production potential of regional semi-arid and arid rangelands has decreased markedly since 1911. Cattle, sheep, and goat numbers have declined during the last decade to their lowest levels in 60 years (Bosch and Theunissen, 1992). However, Bosch and Theunissen (1992) reported a 50% increase in SR in Vryburg District between the periods 1911–1930 (SR = 9.74 ha/LSU/yr) and 1971–1981 (SR = 6.49 ha/LSU/yr).[5] This increase correlated with an increase in the density of stock-water points (Dean and Macdonald, 1994).

Figure 3 illustrates historic livestock numbers in Ganyesa District, as compiled in this study. The decrease in stock numbers in the early 1980s is due to drought (see Fig. 2a). The more general increase has been accompanied neither by an increase in rainfall nor an improvement in veld condition. Agricor (1985) estimated CC to be 10 ha/LSU/yr and actual SRs to be between 11 and 12 ha/LSU/yr in Ganyesa District. Five years later, an independent, nongovernmental, regional development study determined that 49 SADT Farms in Ganyesa District were overgrazed, estimating CC to be only 20 ha/LSU/yr while actual SR was 8 ha/LSU/yr (SETPLAN, 1990).

How can one explain this nearly two-fold discrepancy in estimated CC between the two reports? It is unlikely that CC declined to such a degree

[5]A large stock unit (LSU) is defined as the metabolic equivalent of a 454 kg bovine (Meissner *et al.*, 1983).

in only 5 years, especially since 1985 was during an extended drought while rainfall in 1990 was near normal (see Fig. 2a). The difference lies in how CC was estimated—only the SETPLAN report was prepared in consultation with ecologists.

Agricor has recommended reduced SRs for Ganyesa farms. A 1990 Agricor survey of veld condition on the same 49 farms recommended short-term SRs ranging from 14 ha/LSU/yr to 25 ha/LSU/yr (Kowang *et al.*, 1990b). Unfortunately, this recommendation was weakened by the addition of four conclusions that were either confusing, naive, or misleading. I have quoted the relevant portions of each, added my own paranthetical comments for clarification, and elaborated on why each is problematic.

> 1. Under normal conditions, when the grazing condition is at its climax stage {maximum grass production}, the carrying {capacity} of the area surveyed is 10 ha/LSU/yr.

This conclusion is first of all confusing, as ''grazing condition'' cannot be both ''normal'' and ''at a climax stage'' at the same time. If ''normal condition'' is meant to describe typical seasonal variation in forage availability, then CC estimates should be based on grazing condition averaged across the entire year, not just the ''climax stage.''

> 2. To facilitate a faster improvement of the veld, farms were advised to adhere to a long-term SR of 12 ha/LSU/yr.

This is also confusing given their short-term SR recommendation of 14–25 ha/LSU/yr, as the report failed to define either ''short-term'' or ''long-term.''

> 3. Lack of water also causes bigger areas of some farms to be underutilized with the result that grass becomes moribund.

This statement reveals the perception of the author (a pasture/animal scientist) that the veld is little more than a source of cattle fodder; the statement ignores the important ecological role such ''moribund'' grass plays in fueling veld fires, as described earlier.

> 4. Inequitable distribution of water is one of the factors that is contributing to the degeneration of the grazing because large numbers of animals become concentrated in an area in which water is available.

This conclusion is dangerously misleading. Evidence for the damaging effect of boreholes on rangeland vegetation, including in Africa, has existed for at least 20 years, as mentioned earlier (Glantz, 1976; Picardi and Siefert, 1976). The more ecologically-based 1990 SETPLAN report, prepared the same year, stated quite the opposite.

> Veld can recover from a drought or from grazing if allowed to rest. Previously ungrazed areas are now grazed constantly due to fencelines and borehole technology.

> Fencelines have restricted former communal grazing movement patterns. Cattle have a daily walking range of about 10 km, so once the mean distance between water points is reduced to < 10 km, the whole veld is grazed the year round. Even if fencing and rotational grazing management practices are employed, overgrazing will still occur unless the overall stocking rate is conservative.

The authors of the 1990 SETPLAN report made four conclusions of their own that reveal the failure of cattle farmers to manage grazing in an ecologically sustainable manner:

> 1. Few farmers (including RSA farmers) adhered to recommended veld management systems.
> 2. Farmers generally had a complacent attitude towards veld deterioration.
> 3. The important veld management principle of vegetation resting period breaks down under economic pressure.
> 4. Relatively rigid veld management recommendations are unlikely to be adhered to by livestock farmers with traditionally-based management methods.

The first conclusion above implies that both Black and White farmers were guilty of grazing mismanagement, which begs the question: Ecological factors being equal (same climate, soils, and biota), does SR differ between Black and White farms? I found 1995 stocking records for Black farms in Ganyesa District and compared these to stocking records from nearby White farms, as summarized in Table II.

Note that the apparent decrease in SR at Ganyesa between 1978 (Table I) and 1995 (Table II) may not necessarily indicate a decrease in grazing

Table II. Comparison of 1995 Stocking Rates Between Black and White Farms in Vryburg District[a]

	Hectares	Actual stocking rate as a % of carrying capacity[b]
Black farms[c] (N = 19)		
Range	1626–4577	33–184
Median	2722	76
Average	2792	76
Standard deviation	905	42
White farms[d] (N = 22)		
Range	766–27085	13–127
Median	3305	58
Average	5172	62
Standard deviation	5713	26

[a]Monthly stock census data were available for White farms over a 16-month period, while stock census data for Black farms did not specify the month. However, cattle count data independently gathered and recorded throughout 1995 by animal health officers at the same Black farms agreed closely, when averaged, with the Black farm data summarized here.
[b]Carrying capacity is 10 ha/LSU/yr.
[c]Source: District Agricor Office, Ganyesa.
[d]Source: RSA Department of Agriculture Extension Office, Vryburg.

pressure. Since farmers are struggling to make a profit, the apparent decrease more likely indicates failure to lower CC as bush encroachment proceeded. Madikwe SADT farms ($N = 6$) surveyed had 1995 SRs averaging 73% of CC, which closely agrees with the average of 76% for Ganyesa SADT farms in Table II. This may indicate a regional overestimation of CC by the government.

A student's *t*-test for independent samples revealed that average grazing pressure, as calculated in Table II, was not significantly higher on Black farms than on White farms ($p > 0.10$). However, the discrepancy in average size between Black and White farms was more significant ($p < 0.10$).

The National Grazing Strategy drew attention to problems of uneconomic farm size and poor farm management that presented obstacles to achieving sustainable grazing practices (Vogel, 1994). White farms have no size limitation, so the 3000 ha size limitation on SADT farms gives Black farmers a competitive disadvantage. From the beginning, Agricor decreed that SADT farms should maintain an annual income standard, even during drought years. According to Albanius Dipale, chairman of the Boruakgomo Farmer's Association, an advisory body of 12 SADT farmers at Madikwe, Agricor designated 1500–3000 ha as a "life-sustaining unit," or the minimum area required to achieve a profitable operation. At Madikwe, a few dispossessed White farms up to 30,000 ha in area were divided into 15 SADT farms and advertised for lease—over 600 aspiring Black farmers applied. Hence, the 3000 ha upper limit may have been established to reward as many applicants as possible.

Overgrazing occurs when farmers on smaller farms or farms with high capital investment endeavor to be profitable (Vogel, 1994). White farms in this study, which usually feature much higher capital investment, were also found to be bush-encroached. Even in good rainfall years, cattle farming is not a very profitable venture. Drought subsidies to White farmers have helped them sustain operations as profits decline. Moreover, White farmers tend to be more emotionally invested in their farms because often they have been family owned and operated since the Trekboers from the Cape colony settled over a century ago (Marx, 1993). Meanwhile, Ganyesa District agricultural extension agent Paul Maubane said that only three out of 68 Black farmers in Ganyesa District actually reside on their leased SADT farms, and few make large capital expenditures; most seem to be businessmen just hoping to earn some extra income on the side with minimal investment. In summary, the socioeconomic and cultural forces driving cattle farmers to overstock their land differ between Black and White farmers, but the end result—bush encroachment—is the same.

MADIKWE GAME RESERVE

Bophuthatswana was assimilated into the new North West Province in 1993, and management of MGR was transferred to North West Parks Board (NWPB). From the onset, park managers defined fire as "an integral part of the Madikwe system." Bush thinning, and hence vegetation restoration, would be accomplished "through a combination of fire, browsing, and mechanical means and where unavoidable, with strictly controlled use of appropriate arboricides" (Madikwe Development Task Team, 1994). While it is too soon to claim conclusively that management fires have thinned bush densities, they are achieving marked topkill of the woody overstory canopy, as predicted by previous studies (e.g., Trollope and Tainton, 1986; Bond, 1997). The significance of current efforts by NWPB to remedy bush encroachment in the reserve is best appreciated by first considering the previous land management practices of cattle farmer Bob Brown[6] of the largest annexed farm, which at nearly 30,000 ha would comprise one-half of the future MGR.

Bob Brown, who is White, blamed drought for the lost CC on his farm. His son Bill also mentioned the detrimental impact of a big drought from 1979–1986. Bill remarked, "In 1970, a life-sustaining unit was 800 ha, but now it's 3500 ha!" Bill attributed the lost CC to "drought and overgrazing."

In 1990, Bob Brown had still not vacated his farm even though it had been handed over to BOP from RSA years earlier. Anticipating legal battles to keep his land from being dispossessed, Bob commissioned Simon Kemp, a personal friend and pasture science consultant at North West Cooperative Ltd., to assess the farm's CC. Astonishingly, Kemp determined a CC of 5.2 ha/LSU/yr. This figure conveniently mirrors that of noted South African botanist J. P. H. Acocks, who in 1947 estimated the same CC for the same veldtype *in good condition*. Yet, also in 1990, Agricor advised area farms ($N = 12$) to reduce their SRs to 10–15 ha/LSU/yr because no veld existed in good condition (Kowang *et al.*, 1990a). This SR recommendation actually may be quite liberal, if the 1990 Agricor SR recommendations for Ganyesa District (presented earlier) were any indication. The fact that Bob Brown gave Kemp and his assistant free room and board for a whole month, in addition to paying them, brings Kemp's objectivity into question. Bob Brown and his other son, Bud, were reluctant to provide me with a copy of Kemp's report, claiming it might upset the lawyer preparing their case for land claims court.

Kemp has since left North West Coop, but I interviewed his replacement, pasture scientist Riaan Dames, who did furnish me with a copy of

[6]All farmer names are fictitious to protect their identity.

Kemp's report. When I questioned Dames about Kemp's CC determination, Dames said that the determining formula was designed for highveld (a different veldtype), and that the formula had been altered. He considered the altered formula highly subjective and would not recommend it himself. The report also revealed that Bob had quoted me a bogus figure during our interview: Bob had claimed that Kemp determined a CC of 3.9 ha/LSU/yr, but Kemp's own CC estimates recorded in the report range from 4.18–7.18 ha/LSU/yr for the various soil types found on Brown's farm (which average to the 5.2 ha/LSU/yr figure cited previously). Thus, Bob Brown may have been trying to hide the fact that he had overgrazed his land, as SR data documented by two independent sources reveal in Table III.

Bob Brown and his two sons all stressed that they believed in farming "naturally." Yet they made it clear that they believed burning was "unnatural." When asked if he considered a fire ignited by lightning unnatural, Bob then agreed that lightning was natural, but "with lightning comes rain, so really only the rotten grass burns. Utilized areas won't burn from lightning." Dames flatly disputed the Browns' negative view of fire, stating, "Farmers do not rest the veld long enough before a fire. The grass growth should be vigorous when it's burned."

John Doe, a deceased farmer who lived just north of Brown, was the only farmer in the Madikwe area known to sometimes burn his land. According to Brown, Doe burned "because he understocked. Underutilized grass needs to be burned, or it will rot and cattle won't graze it." In sharp contrast, Greg Stuart-Hill, the original ecological manager of MGR, described Doe as "the one farmer who didn't flog the land."

Bob Brown is now retired, and his two sons own and operate their own farms. Yet all three feel strongly that their farm should be returned to the family and are genuinely disturbed about the large veld fires being ignited inside MGR. They are also concerned that the elephants reintroduced into MGR are seriously damaging the veld. This same opinion was offered by several other farmers interviewed in this study, as well as many

Table III. Stocking Rates (ha/LSU/yr) on Bob Brown's Farm from 1979–1986, According to Two Independent Sources

	1979	1980	1981	1982	1983	1984	1985	1986	Mean
Government[a]	4.2	4.3	3.7	3.7	3.7	3.6	4.2	NA	3.91
Brown[b]	4.9	4.6	4.0	4.0	4.0	3.8	4.6	6.5	4.55

[a]Yearly stocking rates (in ha/LSU/yr) from 1979–1985, as determined by government cattle inspectors.

[b]Yearly stocking rates (in ha/LSU/hr) from 1979–1986 according to Brown's own records, as reported to the Department of Revenue for tax purposes.

Table IV. Comparison of Stocking Rates Between Bob Brown's Farm and Madikwe Game Reserve (MGR)

	Brown[a] (1990)	MGR[b] (1995)	MGR[b] (1996)	MGR[b] (1997)
Game count	4415	11500	13456	13316
Stock-equivalent[c]	1139	5833	6856	7049
Stock count	7033	0	0	0
Total	8172	5833	6856	7049
Area (ha)	28,800	59,527	59.527	59.527
Stocking rate (ha/LSU/yr)	3.5	10.2	8.7	8.4

[a]Source: Bob Brown's farm records.
[b]Source: Adcock (1997).
[c]Conversion factors are means for all age and sex classes of each game species, since age and sex distribution data were not available. Source: Meissner (1982).

tourists who witness elephant destruction of trees that are often not principal encroaching species.

The reintroduction of native fauna into MGR[7] poses a compelling question: How have game SRs in MGR compared to earlier SRs on Bob Brown's farm? Converting game count data to livestock-equivalents allowed this comparison, summarized in Table IV.

Assuming that stock equivalences have been adequately accounted for, Table IV shows that grazing pressure was substantially greater on Brown's farm than in MGR in any year since. (Game populations in MGR prior to 1995 were still mainly being reintroduced, hence aerial surveys were not yet conducted.) Furthermore, since native herbivores include both grazers and browsers, one can expect the vegetation to support more herbivores with diverse dietary preferences than an equal mass of cattle with the same dietary preference. In savannas with indigenous large herbivores, Owen-Smith (1993) found that grazer biomass tends to outweigh browser biomass, and 75–90% of consumption is concentrated on the grass component. Other studies also determined that the impact of elephants on woody browse is overrated as long as the elephant themselves are not overpopulated. Stuart-Hill (1992) found that in Addo Elephant National Park, where elephant occur at high densities, browse consumption amounts to about 8% of estimated production. In Kruger National Park, where elephant occur at lower densities, browse consumption is 7% of estimated production while at Umfolozi Wildlife Park, where elephant are absent, it is 4% (Owen-Smith and Danckwerts, 1997).

[7]Ten thousand animals of 28 species have been released through 1995 (Bophuthatswana National Parks Board, 1995/96), amounting to the largest animal reintroduction program ever undertaken.

GRAZING MANAGEMENT RECOMMENDATIONS

Advances in our understanding of savanna ecological processes have not been matched by developments in the theory and practice of range assessment (Friedel, 1991). Although the spatial and temporal stochasticity of ecological processes in arid and semi-arid savannas (Coughenour, 1991) complicates assessments of how various grazing management strategies affect these ecosystems, overgrazing can result from any management method unless SR is reduced, particularly during drought (McCabe, 1991). Lake Turkana pastoralists in northern Kenya avoid rangeland degradation during drought with dramatically reduced herd sizes to levels far below CC (McCabe, 1987). Ultimately, the most sustainable grazing management strategy is an opportunistic one, where stock numbers are managed to reflect changing vegetation condition (Westoby *et al.*, 1989; Behnke and Scoones, 1992). At the broader scale of environmental policy, this is an example of "adaptive management" because it emphasizes environmental feedbacks in shaping policy. An adaptive management strategy is iterative and learning-based because management policy and the state of the resource co-evolve (Berkes and Folke, 1998).

Large tracts of savanna have entered an undesirable, perhaps irreversible, ecosystem steady state due to severe bush encroachment resulting from chronic overstocking and fire suppression. Reductions in SR, or perhaps even total cattle exclusion, may no longer suffice to revert these systems to their former, more desirable condition (Friedel, 1991). The time has long since arrived for grazing policymakers to advocate fire management and for cattle farmers to apply it.

Academic knowledge regarding fire effects on rangeland vegetation progressed from general hostility in the early 1920s to widespread acceptance by the 1950s (Scott, 1984), yet improved understanding of the essential role of fire in savanna ecology has failed to reach cattle farmers, who are most in need of it. There is an obvious need to educate cattle farmers, but this may be difficult, particularly with regard to Afrikaner farmers. Afrikaners have historically developed into, and prefer to view themselves, as a hardy, proud, independent people instinctively distrustful of government intrusion.[8] It became apparent through my interviews with local Afrikaner farmers that they viewed cattle grazing as not only the best *use* for the veld but also its most appropriate *purpose.*

[8]The cultural and philosophical parallels between Afrikaner and American ranchers are striking. An insightful, amusing anecdote is found on the official road sign marking the city limits of the district capital of Vryburg: "VRYBURG: Texas of South Africa".

On the other hand, cattle farmers, be they Black or White, are acutely aware of the bush encroachment problem and desire a solution. All seven farmers interviewed on farms near Ganyesa were only too willing to dismiss using fire as a management tool. Yet four out of ten farmers on farms situated near MGR's periphery had experimented with fires on their own land in 1996, the year interviews were conducted. The probability that this difference in attitude was due to chance is less than 10% ($p < 0.10$) according to a chi-squared test. Attitudes about fire are evidently shifting among farmers who are noticing the thinning effect fire is having on bush densities within MGR.

For example, one Madikwe farmer, Jim Jones, is still bitter over an ill-timed 1992 fire that destroyed much of the winter forage on his farm, causing him considerable economic hardship. The fire jumped onto his farm from MGR very early in the dry season, where it had ignited from a lightning strike. Yet surprisingly, Jones acknowledged that a fire appropriately timed at the end of the dry season can be useful for thinning bush and rejuvenating grass growth. Most noteworthy of all, Jones was observed starting veld fires on his own farm in 1996.

In the course of this research I encountered only one farmer, an Afrikaner at Madikwe named Sam Smith, who appreciated the link between fire suppression and bush encroachment. He regarded the government's CC estimation of 7 ha/LSU/yr for the area as "impossible because the veld is too bushy." Smith continued, "The government, instead of offering drought subsidies, should offer subsidies to eradicate bush! They should also offer a fire management program. Fires are needed to control bush."

The 1990 nongovernmental SETPLAN development study (prepared in consultation with two ecologists) made some useful, sustainable grazing management recommendations:

1. Rotate grazing between four camps by making water available at only one camp at any time, insuring that three camps will be rested.
2. Establish veld "reserves" where water will not be reticulated, to act as buffers to regional over-utilization of the natural resource base.
3. Introduce game species that browse, move freely, do not require continual management, and are communally owned, cropped and marketed.

Note that while these are sound recommendations, fire as a management tool is unmentioned. Despite the consensus among ecologists that fire is a vital component of savanna ecology, this knowledge has not sufficiently diffused to grazing managers.

CONCLUDING COMMENTS

The reintroduction of native herbivores and veld fires into MGR offers a hopeful example of how bush may be controlled ''naturally,'' using native browsers and fire. Game animals require less intensive management than cattle because game are better adapted to the environment, and game provide the added economic benefit of attracting tourists and hunters. The DA should collaborate more closely with NWPB, perhaps by providing free MGR tours to regional cattle farmers so they can view for themselves the positive effect fires and native browsers are having on bush control. Afrikaner farmers are more likely to be receptive to this ''carrot'' approach than to a ''stick'' approach of stricter government SR regulations, which are difficult to enforce. Another smaller yet promising example was provided by one of the DA's own extension agents, Jannie van den Heever, who I witnessed offer a training seminar to educate agricultural extension officers at the Ganyesa District Agricor Office about the ecological causes and effects of bush encroachment. More importantly, he presented guidelines on how to use high intensity veld fires as a management tool for bush control.

The DA should capitalize on these hopeful examples by recognizing the importance of fire and browsers in savanna ecology and dynamically adapting SR recommendations according to changing veld conditions, especially during drought. The DA should also replace its current drought relief program with a bush control program that features fire and native browsers as veld management tools.

The causes of regional bush encroachment in South African rangelands, and the promising example of bush remediation occurring locally within MGR, are relevant for rangeland managers worldwide. Fire and herbivore disturbance regimes largely determine the balance between woody plants and grasses in global savannas. Management strategies that ignore this fact by altering these vital disturbance regimes eventually have undesirable ecological and economic consequences. Ecological sustainability, and not just economic productivity, should be used as a criterion for evaluating cattle farm success. Grazing management will prove sustainable only once existing ecological knowledge is applied.

ACKNOWLEDGMENTS

This research was made possible by graduate fellowships from the U.S. EPA, the Cooperative Institute for Research in Environmental Sciences and the Biosphere-Atmosphere Research Training Program at the University of Colorado. I wish to thank Bob Scholes and Alfred Rasweswe for supplying

information and Moses Moeti for Afrikaner translations. Roger Pielke, Jr., John Magistro, and Carol Wessman provided helpful critical reviews.

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